Fabrication of Au Nanopore on Pyramid using Various Electron and Ion Beam Techniques

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The fabrication of the nanopore on pyramid has been examined using various high energy electron beam irradiation and focused ion beam (FIB) milling techniques. The surface modification of the Au nanopore formation on the bowl-shape crater type hole using FIB and high energy electron beam techniques were successfully controlled. Initially, the nanopores on the (25x 25) pyramidal array were fabricated using Si microfabrication techniques. For the fabricated oxide nanopore with opened apex of the pyramid, the metal deposition was carried out (Fig. 1.). For the 200 nm Au deposited oxide pyramidal membrane on the apex, the aperture was milled using 30 keV Ga Ion FIB milling. The drilled aperture was founded to be a bowl-shape crater with 421 nm outside diameter. Then, the FIB scanning with scanning area (1x 1) μm^2 with 9.7 pA, 30 keV Ga ion for 1 sec was performed successively. After first 1 sec scanning, the diameters of the bottom of the crater and the pore were found to be 326 nm and 175 nm, respectively (Fig. 2.a.). With another 1 sec. FIB scans, the diameters of the dark bottom and the pore were shunk to 280 nm and 30 nm, respectively. Upon final 3 sec FIB scan, the diameter of the bottom of the crater is shrunk to 270 nm and the aperture was completely closed. This can be attributed to viscous flow of the Au atoms during Ga ion irradiation[1]. The fabrication of the nano-channel with ~ 5nm width in the Au dunes from ~ 140 nm wide Au gap was also tried in Fig. 3. After 0.5 keV electron energy exposure using FESEM, the narrowing of the nano-river with 2.8 nm width was also presented. The fabricated pyramidal arrays were shown and the nanopore was formed at its apex of the pyramid(Fig. 4.: top right). The Ga ion milled nanopore with 30 nm diameter (center) and the 18.9 diameter Au nanopore (bottom left) along with the ring of the Au island was presented.

[1] A. J. Storm, J. H. Chen, X.S. Ling, H.W. Zanbergen, C. Dekker, Nature Materials 2, 537 (2003).
[2] C.J. Lo, T. Aref, A. Bezryadin. Nanotechnology 17, 3264 (2006).

Figure 1. The oxide aperture on the pyramid was microfabriated followed by Au, or Al deposition by two step sputtering. The Au and Al nanoflowers were presented.

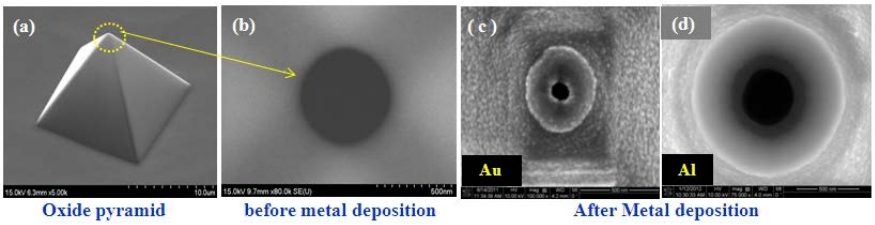

Figure 2. After FIB milling, the scanning of (1x1) μm^2 using 9.7pA μm^2, 30 keV was carried out. The reduction of the nanopore on the bowl-shape crater was shown after an successive 1 sec scan (a), another 1 sec scan (b), followed by an additional 1 sec scan , and 3 sec scan.

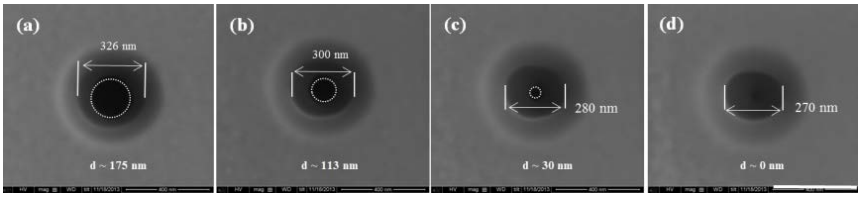

Figure 3. Nano-river reduction using 0.5 keV FESEM irradiation with 10 μA emission current setting and probe current setting at 10 position. The narrowing of the nanoriver with 137 nm wide before electron beam exposure in (a), after FESEM electron exposures, the ~ 5 nm wide nano-channel and the 2.8 nm wide nano-stream in the Au dunes were shown in (b) and (c), respectively.

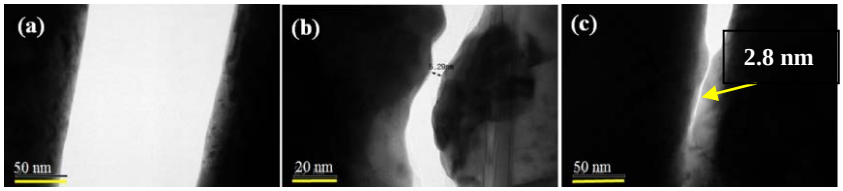

Figure 4. The nanopores fabricated by FIB ion beam scanning and FESEM electron beam exposure were presented in the pyramidal array. The pyramid was shown (top right), the FIB milled nanopore with 30 nm diameter (center), and 18.9 nm diameter nanopore with the ring of Au islands using TEM electron beam exposure (bottom left).